

April 27, 1893.

The LORD KELVIN, D.C.L., LL.D., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read :—

- I. "On the Results of an Examination of the Orientation of a number of Greek Temples, with a view to connect these Angles with the Amplitudes of certain Stars at the time these Temples were founded, and an endeavour to derive therefrom the Dates of their Foundation by consideration of the Changes produced upon the Right Ascension and Declination of the Stars arising from the Precession of the Equinoxes." By F. C. PENROSE, F.R.A.S. Communicated by Professor J. NORMAN LOCKYER, F.R.S. Received December 13, 1892.

(Abstract.)

This investigation is supplementary to Mr. Lockyer's examination of the orientation of the Egyptian temples, in the course of which he has cited passages translated from hieroglyphics, showing most distinctly that there was a connexion between the foundation of those temples and certain stars. He has also shown that the structure of the temples demonstrates that the light from these stars must have been admitted at their rising or setting along the axis of the temples through the doorways, and that in certain temples the doorways have been altered in such a way as to follow the amplitude of the star as it changed, owing to the precession of the Equinoxes, and that in some cases a new temple had been founded alongside of an older one for the same purpose.

Although there does not seem to be any historical or epigraphical record of such a nature in Greece, the architectural evidence is not wanting. On the Acropolis of Athens there are two temples, both dedicated to Minerva, lying within a few yards of one another, both apparently oriented to the Pleiades, the older temple to an earlier position of the star group, and the other to a later one. At Rhamnus there are two temples almost touching one another, both following (and with accordant dates) the shifting places of Spica. In a temple

at Ægina a doorway placed excentrically in the west wall of the cella was adapted for the observation of a setting star.

A clue is given for finding out the dates of the foundations of temples oriented to stars by means of the changes produced upon them by the precession of the Equinoxes, a movement which induces a divergence between the latitudes and longitudes of stars, and their places reckoned in declination and right ascension; so that after the lapse of 200 or 300 years a star which rose or set in the direction of the axis of a temple would have passed to a different amplitude, so as to be no more available for observation, as before, from the adytum.

In the earlier ages of Greek civilisation the only accurate measure of time by night was obtained by the rising or setting of stars, and these were more particularly observed when heliacal, or as near as possible to sunrise. For the purpose of temple worship, which was carried on almost exclusively at sunrise, the priests would naturally be very much dependent for their preparations on the heliacal stars as time warners.

The orientation of temples may be divided into two classes, solar and stellar. In the former the orientation lies within the solstitial limits; in the latter it exceeds them. In Greece there are comparatively few of the latter class.

In the lists of temples which follow, all the orientations were obtained from azimuths taken with a theodolite, either from the Sun or from the planet Venus. In almost every case two or more sights were observed, and occasionally also the performance of the instrument was tested by stars at night. The heights subtended by the visible horizon opposite to the axes of the temples were also observed.

The first list comprises twenty-seven intra-solstitial temples :

7 examples from Athens.	1 example from Sunium.
3 " Olympia.	1 " Corinth.
2 " Epidaurus.	1 " Bassæ.
2 " Rhamnus.	1 " Ephesus.
2 " Ægina.	1 " Platæa.
1 " Tegea.	1 " Lycosura.
1 " Nemea.	1 " Megalopolis.
1 " Corfu.	1 " Argos.

For all these the resulting solar and stellar elements are given, with the approximate dates of foundation, similarly to the following specimen, namely, that of the Temple of Jupiter at Olympia.

Olympia, lat. $37^{\circ} 38' N$.

Temple of Jupiter.	Orientation angle.		Stellar elements.	Solar elements.	Name of star.
	$262^{\circ} 37' 46''$	Amplitude, star or sun	$8^{\circ} 38' 0'' N.$	$7^{\circ} 22' 14'' N.$	
		Corresponding altitude	$3^{\circ} 0' 0'' E.$	$1^{\circ} 42' 0'' E.$	
		Declination	$+8^{\circ} 40' 0''$	$+6^{\circ} 52' 22''$	
		Hour angles	$6^h 11^m 37^s$	$7^h 34^m 52^s$	
		Depression of sun.	$14^{\circ} 12' 0''$	
		Right ascension	$23^h 40^m 0^s$	$1^h 3^m 5^s$	
		Approximate date ..	B.C. 740	Apr. 6.	

This example has been selected from the rest of the list, because this temple has been chosen for the purpose of showing the method of procedure in working out the elements from the observations, those, namely, of the orientation angle, and of the height of the visible horizon.

A few general remarks, however, seem required respecting the Sun's and star's altitude, and the Sun's depression when the star is to be observed.

For a star to be seen heliacally, it is necessary that the Sun should be just sufficiently below the horizon for the star to be recognised. According to Biot, Ptolemy, speaking of Egypt, has recorded this to be about 11° . But where, as generally in Greece, there are mountains screening the glow which at such times skirts the true horizon, it seems fair at any rate for a first magnitude star to consider 10° as sufficient. I have myself seen Rigel in the same direction as the Sun when elevated $2^{\circ} 40'$ above the sea horizon, the Sun being less than 10° below. Obviously an observer looking from a dark chamber in a well known direction would be more favourably situated.

It is proper to allow about 3° of altitude for a star to be seen above low clouds and the hazy glow which skirts the horizon. The Sun's light, however, seems to be very effective at a lower altitude, and when he appears over a mountain of 2° or 3° altitude the angle may properly be reduced by $20'$ or $25'$, partly for refraction, and partly because a small segment only of the disk is sufficient for illumination.

The method I have pursued in working out the example of the Temple of Jupiter at Olympia is as follows.

The orientation angle, measured from the south point round by way of west and north, is $262^{\circ} 37' 46''$, which is equivalent to an amplitude of $+7^{\circ} 22' 14''$. The eastern mountain subtends an angle of $2^{\circ} 4'$. For reasons above given, the solar altitude may be

taken as $1^{\circ} 42'$, but that of the star, 3° . Combining these values with the latitude, viz., $37^{\circ} 38'$, and using the formula

$$\sin \delta = \cos \text{zen. dist.} \times \cos \text{colat} + \sin \text{zen. dist.} \times \sin \text{colat} \times \sin \text{ampl.},$$

we obtain for the star a declination of $+7^{\circ} 40'$, and for that of the Sun $+6^{\circ} 52' 22''$. This latter, with the ecliptic obliquity of about 800 years B.C., determines the Sun's right ascension to have been $1^{\text{h}} 3^{\text{m}} 15^{\text{s}}$.

The next step is to enquire if there be any bright star or star group which, at a date consistent with archæological possibility, would have had a declination near to the above-named place, and would also have been heliacal.

Such a star would have required about $6^{\text{h}} 8^{\text{m}}$ to pass from 3° altitude to the meridian, and it would have required to have been about $1\frac{1}{4}^{\text{h}}$ in advance of the Sun to allow it to be seen. The approximate R.A. of such star would therefore be about $23^{\text{h}} 40^{\text{m}}$, and its declination, as already stated, must be about $7^{\circ} 40' \text{ N.}$

For trials I have used a stereographic projection of the sphere taken on the pole of the ecliptic, but showing also R.A. hours and parallels of declination. Any place on this projection may be chosen and marked on a superimposed sheet of tracing paper, and then if the tracing paper is turned round upon the pole of the ecliptic as a centre, so that the straight line drawn upon it, which in the first instance joined the two poles marked on the projection, is carried round to an angle equal to the amount of precessional movement under consideration, if there be a suitable star marked on the projection the point selected for trial will pass over it or near it, and after the star has been thus roughly pointed out the more exact calculations may be proceeded with. By this process in the case before us the tracing-paper mark coincided almost exactly with the place of α Arietis, and for this star the particulars were carefully computed which have been given in the list of elements.

It should be noticed that there are in every case of intra-solstitial temples four possible solutions of this step. The Sun's amplitude may be due either to the vernal or the autumnal place, and the star might have been heliacal either at its rising or setting. In every instance all these four alternatives have been tried by the preliminary search method, and in every case in temples of old foundation an heliacal star has resulted from one or other of the trials, but never more than one.

The star which has been found as above for the Temple of Jupiter is no other than the brightest star of the first sign of the Zodiac, and therefore peculiarly suited to that god. The same star is connected with the early temple of Jupiter Olympius at Athens.

In intra-solstitial temples, by the nature of the case, the stars are

almost entirely confined to the Zodiacal constellations, and consequently suitable stars are very much limited in number.

Another very great limitation arises from the consideration that, to have been of any service as a time warner, the star must have been heliacal, and when these two limitations are taken into account, it becomes improbable to the greatest degree that there should always have been a suitable star unless it had been so arranged by the builders of the temple.

In about two-thirds of the cases which I have investigated the dates deduced from the orientations are clearly earlier than the architectural remains now visible above the ground. This is explained by the temples having been rebuilt upon old foundations, as may be seen in several cases which have been excavated, of which the archaic Temple of Minerva on the Acropolis of Athens and the Temple of Jupiter Olympius on a lower site are instances. There are temples also of a middle epoch, such as the examples at Corinth, Ægina, and the later temples at Argos and at Olympia (the Metroum at the last named), of which the orientation dates are quite consistent with what may be gathered from other sources.

Besides the list of intra-solstitial temples already given, I have particulars of five for which I have been unable to find an heliacal star. They are all known to be of recent foundation, when other methods of measuring time had been discovered. The solar axial coincidences were no doubt in all these cases connected with the great festivals of these temples. It was clearly the case in two of them.

At the Theseum at Athens the date was either October 10 or March 2. The *Thesea* festival is reckoned to have been on October 8 or 9. For the later Erechtheum the day would have been April 8 or September 3. The great festival of this temple is put down for September 3.

Leaving the solar temples, we find that the star which was observed at the great Temple of Ceres must have been Sirius, not used, however, heliacally—although this temple is not extra-solstitial—but for its own refulgence at midnight. The date so determined is quite consistent with the probable time of the foundation of the Eleusinian Mysteries and the time of year when at its rising it would have crossed the axis at midnight agrees exactly with that of the celebration of the Great Mysteries.

It is reasonable to suppose that when, as in the case of Sirius at Eleusis, brilliant stars were observed at night, the effect was enhanced by the priests by means of polished surfaces.

Herodotus, speaking of a temple at Tyre (B. II, 44), says:—

“Καὶ ἐν αὐτῷ ἦσαν στήλαι ἐνός, ἣ μὲν χρυσοῦ ἀπέφθου, ἣ δὲ σμαράγδου λίθου, λάμποντος τὰς νύκτας μέγας.”

(Two shafts, one of pure gold, the other of emerald, which shone remarkably at night.)

Of a list of seven extra-solstitial temples which are named, five are more particularly noticed, viz. :—

A temple at Mycenæ and one near Thebes, which are built nearly north and south, but which probably, as was the case at Bassæ, had eastern doorways. The star, α Arietis, which suits the first, seems to point out the dedication of this temple to Jupiter. The other is very remarkable, and connects the Bœotian Thebes with the great Egyptian city; the star was γ Draconis. Thebes was called the City of the Dragon, and tradition records that Cadmus introduced both Phœnician and Egyptian worship. Three of the temples lay more nearly at an angle bisecting the cardinal points; these are Diana Propylæa at Eleusis, a small temple (not yet named) lately discovered at Athens, and the Temple of Venus at Ancona, recovered by means of the walls of a church built upon its traditional site. In these temples the star observed at the first seems to have been Capella, the time of the year when it shone axially at midnight agreeing with that of the celebration of the Little Mysteries, and in the other two the star was Arcturus.

- II. "On the Coloration of the Skins of Fishes, especially of Pleuronectidæ." By J. T. CUNNINGHAM, M.A. Oxon., Naturalist on the Staff of the Marine Biological Association, and CHARLES A. MACMUNN, M.A., M.D. Communicated by Professor E. RAY LANKESTER, F.R.S. Received March 6, 1893.

(Abstract.)

In normal specimens of the majority of the Flat Fishes, *i.e.*, of the family Pleuronectidæ, the upper side is pigmented, the lower side opaque white, the colours and markings being characteristic of the species. In symmetrical Fishes which swim vertically the dorsal surface is pigmented, the ventral almost or entirely destitute of pigment. Where the pigment is absent or in small quantity the characteristic silvery brilliancy and iridescence of Fishes' skins is exhibited. It has long been known that the pigment in the skins of Fishes and Amphibia is contained in chromatophores provided with contractile radiating processes, and that the iridescence and brilliant reflection of light is due to special anatomical elements of fixed form, all these elements being placed in the category of connective tissue cells. But exact and detailed descriptions of these coloration elements in Fishes are not available. The most complete account of them is that given by G. Pouchet in his memoir on the "Changement de Colora-